INDOOR AIR QUALITY ASSESSMENT

Milford Highway Department
1 Front Street
Milford, Massachusetts

Prepared by:
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Center for Environmental Health
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of Paul Mazzuchelli, Director of the Milford Board of Health, an indoor air quality assessment was conducted at the Milford Highway Department (MHD) Facility at 1 Front Street, Milford, Massachusetts. This assessment was conducted by the Massachusetts Department of Public Health's (MDPH), Center for Environmental Health (CEH). On March 3, 2005, a visit to conduct an indoor air quality assessment was made to the MHD by Cory Holmes, an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program. The assessment was prompted by employee complaints of reoccurring pneumonia, bronchitis and other respiratory ailments. The MHD is a cinderblock aluminum-sided structure that was built in 1982. The facility consists of a mechanics' bay, a large garage, office space, locker room and kitchen/break room. At the time of the assessment, the second floor was unoccupied and in the process of being converted to recreation and berthing space for overnight staff.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter were conducted with a TSI, P-Trak™ Ultrafine Particle Counter (UPC) Model 8525. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID).

Results

The MHD has an employee population of approximately 15 and can be visited by up to 10 members of the public on a daily basis. The tests were taken under normal operating conditions. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million (ppm) parts of air in all areas surveyed, indicating adequate air exchange. Mechanical ventilation is provided by a heating, ventilating and air conditioning (HVAC) system. A rooftop air handling unit (AHU) equipped with high efficiency pleated air filters introduces fresh outdoor air to the building (Pictures 1 and 2). Conditioned outside air is distributed through ducted ceiling vents and returned to the AHUs by ducted ceiling-mounted return vents (Pictures 3 and 4). Thermostats that control the HVAC system have fan settings of “on” and “automatic”. Thermostats were set to the “automatic” setting during the assessment (Picture 5). The automatic setting on the thermostat activates the HVAC system at a preset temperature. Once the preset temperature is reached, the HVAC system is deactivated. Therefore, no mechanical ventilation is provided until the thermostat re-activates the system.

Local mechanical exhaust ventilation systems are installed in the garage and mechanics’ bay to remove airborne pollutants (e.g., odors, fumes, carbon monoxide and other products of combustion). The systems are described in detail under the Specialized Local Exhaust portion of this report.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of occupancy. In order to have proper ventilation with a mechanical ventilation system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix A.

Temperature readings were measured in a range of 59° F to 69° F, which were in most cases slightly below the lower end of the MDPH recommended comfort range. The lowest temperature (59° F), was measured in the garage, where bay doors frequently open and close. The MDPH recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

Relative humidity measurements ranged from 19 to 26 percent, which were also below the MDPH recommended comfort guidelines. The MDPH recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. Relative humidity would be expected to drop below comfort levels during the heating season. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Specialized Local Exhaust

Under normal conditions, a garage/public works facility can have several sources of environmental pollutants present from the operation of vehicles. These sources of pollutants can include:

- Vehicle exhaust containing carbon monoxide and soot;
- Vapors from diesel fuel, motor oil and other vehicle liquids which contain volatile organic compounds (VOCs);
- Water vapor from vehicle washing equipment; and
- Rubber odors from new vehicle tires.

Of particular importance is vehicle exhaust. In order to assess whether contaminants generated by vehicles were migrating into occupied areas of the MHD, measurement for airborne particulates in combination with carbon monoxide measurements were used to identify sources of combustion products.

The use of fossil fuel-powered equipment (propane heaters, diesel or gasoline-powered vehicles, acetylene welding, etc.) can produce carbon monoxide. Using carbon monoxide solely to detect sources of combustion pollutants has a major drawback. If the source of combustion pollutants is allowed to dilute in a large volume of air within a building, carbon monoxide concentrations may decrease below the detection limits of equipment. The process of combustion also produces airborne liquids, solids and gases (NFPA, 1997). The measurement of airborne particulates, in combination with carbon monoxide measurements can be used to identify the source of combustion products.

Of the materials produced by the process of combustion, carbon monoxide can produce immediate, acute health effects upon exposure. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within the rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The US Environmental Protection Agency has established National Ambient Air Quality Standards (NAAQS) for exposure to carbon monoxide in outdoor air. Carbon monoxide levels in outdoor air must be maintained below 9 ppm over a twenty-four hour period in order to meet this standard (US EPA, 2000). *Carbon monoxide should not be present in a typical, indoor environment.* If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide measurements were non-detect or ND. Carbon monoxide levels indoors at the MHD measured 0-2 ppm (Table 1), most likely the result of exhaust emissions from vehicles operating in the garage.

The combustion of fossil fuels can produce particulate matter that is of a small diameter (10 μm) which can penetrate into the lungs and subsequently cause irritation. For this reason, a device that can measure particles of a diameter of 10 μm or less was also used to identify pollutant pathways from vehicles into the occupied areas. Inhaled particles can cause respiratory irritation.

MDPH air monitoring for airborne particulate was conducted with a TSI, P-Trak™ Ultrafine Particle Counter (UPC) Model 8525, which counts the number of particles that are suspended in a cubic centimeter (cm^3) of air. This type of air monitor is useful as a screening device, since it can be used to trace and identify the source of airborne pollutants by counting the actual number of airborne particles. The source of a producer of particles can be identified by moving the UPC through a building towards the highest measured concentration of airborne particles. Measured levels of particles/cm^3 of air increases as the UPC is moved closer to the source of particle production.

The primary purpose of these tests at the MHD was to identify and reduce/prevent pollutant pathways. Air monitoring for ultrafine particles (UFPs) was conducted around doors with access to the garage and mechanics bay, as well as within areas on first floor of the facility both adjacent and away from the garage and mechanics bay. Measurements were taken during normal operations. The highest readings for UFPs were taken in the garage and mechanics bay after vehicle operation and welding activities. Higher UFP readings would be expected during these activities.

As mentioned previously, the MHD is equipped with a mechanical exhaust system to remove exhaust emissions and other pollutants from the building. The local exhaust system in the garage consists of two large exhaust vents located at the front of the engine bay (Pictures 8 and 9). Four make up air vents are installed on the southwest wall of the garage (Picture 10) to pressurize the engine bay toward the exhaust vent. The automatic activation of this system appears to be dependent on the triggering of carbon monoxide chemical sensors (Pictures 11 and 12). Once a pre-set reading is exceeded, the local exhaust system is activated to introduce fresh air and remove exhaust emissions. Therefore, no mechanical exhaust ventilation is provided until the set-point is exceeded to activate the system. This type of chemical sensor activated system is dependant on accurate measurements of airborne contaminants. MHD personnel could not identify the last time the system was serviced and/or calibrated. MHD staff did, however, report that the system could be manually over-ridden and that it is activated *as needed* using a wall switch.

The mechanical exhaust system in the mechanics bay also consists of a large exhaust fan on the exterior wall (Picture 13); however, unlike the garage; there are no outdoor air make-up vents. Instead, a passive vent is installed in the common wall between the mechanics bay and garage to provide make up air (Picture 14). Drawing air from the garage instead of from the outside can also draw-in airborne pollutants present in the garage (e.g., vehicle exhaust). In addition, drawing air from the garage can also compete with and reduce the effectiveness of the local exhaust system in the garage.

Several potential pathways for exhaust emissions and other pollutants to migrate into occupied areas were identified. The doors to the garage and mechanics' bay had spaces beneath the door where light could be seen penetrating. The door to the mechanics bay also did not close completely (Picture 15). The ceiling/walls of the garage and mechanics bay are penetrated by holes for utilities. If they are not airtight, these holes can be potential pathways for particles to migrate into occupied areas. Each of these conditions presents a pathway for air to move from the garage and mechanics' bay to adjacent areas. In order to explain how these pollutants may be impacting adjacent areas, the following concepts concerning heated air and creation of air movement must be understood.

- Heated air will create upward air movement, a condition known as the stack effect.

- Cold air moves to hot air, which creates drafts.
- Negative pressure is created as heated air rises. This pressure in turn draws cold air to the equipment creating heat (e.g., vehicle engines).
- Combusted fossil fuels contain heat, gases and particulates that will rise in air. In addition, the more heated air becomes the greater airflow increases.
- The operation of HVAC systems (including rest room exhaust vents if operating) can create negative air pressure, which can draw air and pollutants from the garage and mechanics' bay.

Each of these concepts has influence on the movement of airborne pollutants to adjacent areas. As motor vehicles operate indoors, the production of vehicle exhaust in combination with cold air moving from outdoors through open exterior doors into the warmer garage and mechanics' bay can place them under positive pressure. Positive pressure within a room will force air and pollutants through spaces around doors, utility pipes and other holes in walls, doors and ceilings. To reduce airflow into adjacent areas, sealing of these pollutant pathways should be considered.

Microbial/Moisture Concerns

A number of areas had water-stained, missing or damaged ceiling tiles (Picture 6). Occupants reported that ceiling tiles became damaged as a result of leaks from the sprinkler system that have since been repaired. Active roof leaks were also reported; MHD officials were reportedly working with a roofing contractor to identify and repair these leaks. Water-damaged ceiling tiles can provide a source for mold growth and should be replaced after a moisture source or leak is discovered and repaired. Missing and/or damaged tiles can provide a means for dust and particulates that accumulate in the ceiling plenum to move to occupied areas.

Spaces between the sink countertop and backsplash were noted in the kitchen (Picture 7). Improper drainage or sink overflow can lead to water penetration. If the seam is not watertight, water can penetrate and collect behind the countertop or within cabinets. Like other porous materials, if these materials become wet repeatedly they can provide a medium for mold growth. The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommend that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur.

Other Concerns

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were ND. A TVOC measurement of 13.2 ppm was measured in the mechanics' bay while occupants were spray-painting. The level of TVOCs was reduced to 1.0 ppm within 5 minutes via the local exhaust system (Table 1). A parts washer containing solvents and open containers of oil were also observed in the mechanics' bay, which can contribute to the off-gassing of TVOCs (Pictures 16 and 17).

Finally, mechanical exhaust ventilation was not functioning in several restrooms during the assessment. Exhaust ventilation is necessary in restrooms to remove moisture and to prevent restroom odors from penetrating into adjacent areas.

Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. Continue to operate the garage vent system with manual timer. Consider installing an automatic control to activate the exhaust system as garage doors open.
2. Contact the manufacture and/or installer regarding the operation and calibration of the of the chemical sensor/local exhaust ventilation system. Maintain and calibrate it in accordance with the manufacturer's instructions.
3. Contact an HVAC engineering firm for possible solutions (e.g., roof) for providing outside make up air for the mechanic's bay. Continue to operate local exhaust system in mechanics' bay during hours of occupation. Due to the type of materials used (e.g., solvents, paints, fuels), consider installing an automatic timer to operate the system continuously during occupied hours.
4. Keep all doors accessing the garage and mechanics' bay closed at all times.

5. Ensure doors around the garage and mechanics' bay fit completely flush with threshold. Seal doors on all sides with foam tape, and/or weather-stripping. Consider installing weather-stripping/door sweeps on both sides of doors with access to the engine bay to provide a duel barrier. Ensure tightness of doors by monitoring for light penetration and drafts around doorframes.
6. Identify and seal any utility holes in both the garage and mechanics' bay and their terminus to reduce/eliminate pollutant paths of migration.
7. Continue to change filters for HVAC equipment as per the manufacturer's instructions or more frequently if needed.
8. Operate both supply and exhaust ventilation continuously during periods of building occupancy independent of thermostat control to maximize air exchange. Consider setting thermostat controls to the "on" position to provide constant supply and exhaust ventilation.
9. Consider having ventilation systems re-balanced every five years by an HVAC engineering firm.
10. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

11. Ensure roof leaks are repaired. Repair/replace any remaining water-stained, missing or damaged ceiling tiles. Examine areas above these tiles for microbial growth. Disinfect with an appropriate antimicrobial where necessary.
12. Seal spaces around sink to prevent water-damage to the interior of cabinets and adjacent wallboard. Inspect wallboard for water-damage and mold/mildew growth, repair/replace as necessary. Disinfect areas of microbial growth with an appropriate antimicrobial as needed. Consider replacing with a one-piece, molded countertop.
13. Repair/replace restroom exhaust motors.
14. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

References

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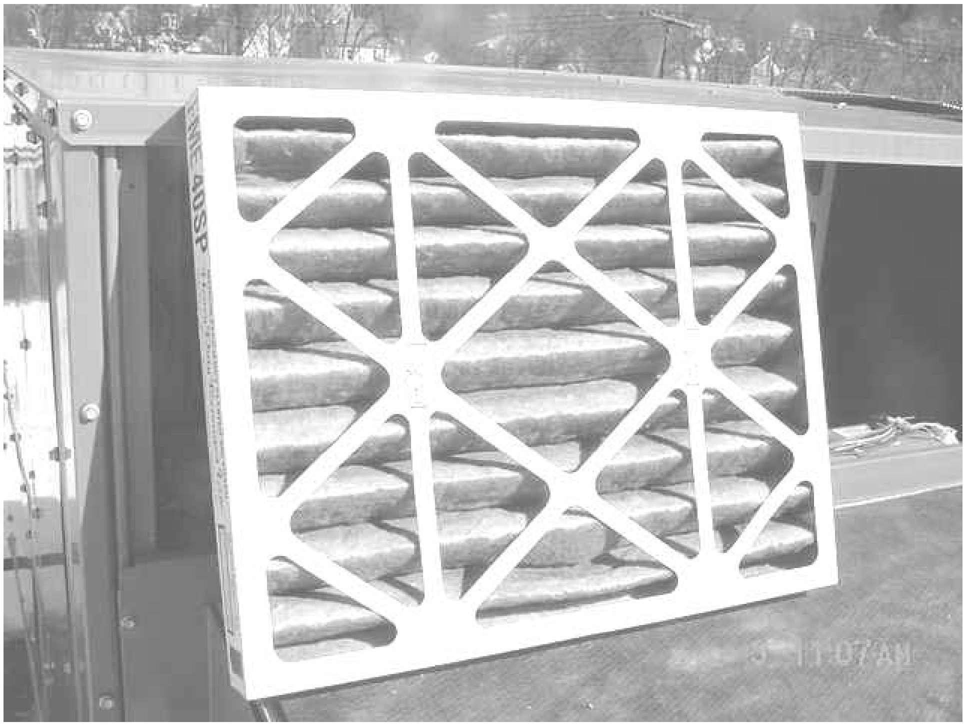
Picture 1

Rooftop Air Handling Unit

Picture 2



High Efficiency Pleated Air Filters Installed in Air Handling Unit

Picture 3

Ceiling-Mounted Supply Air Diffuser

Picture 4

Ceiling-Mounted Return Vent

Picture 5

Thermostat for HVAC System With Fan Set to “Auto”

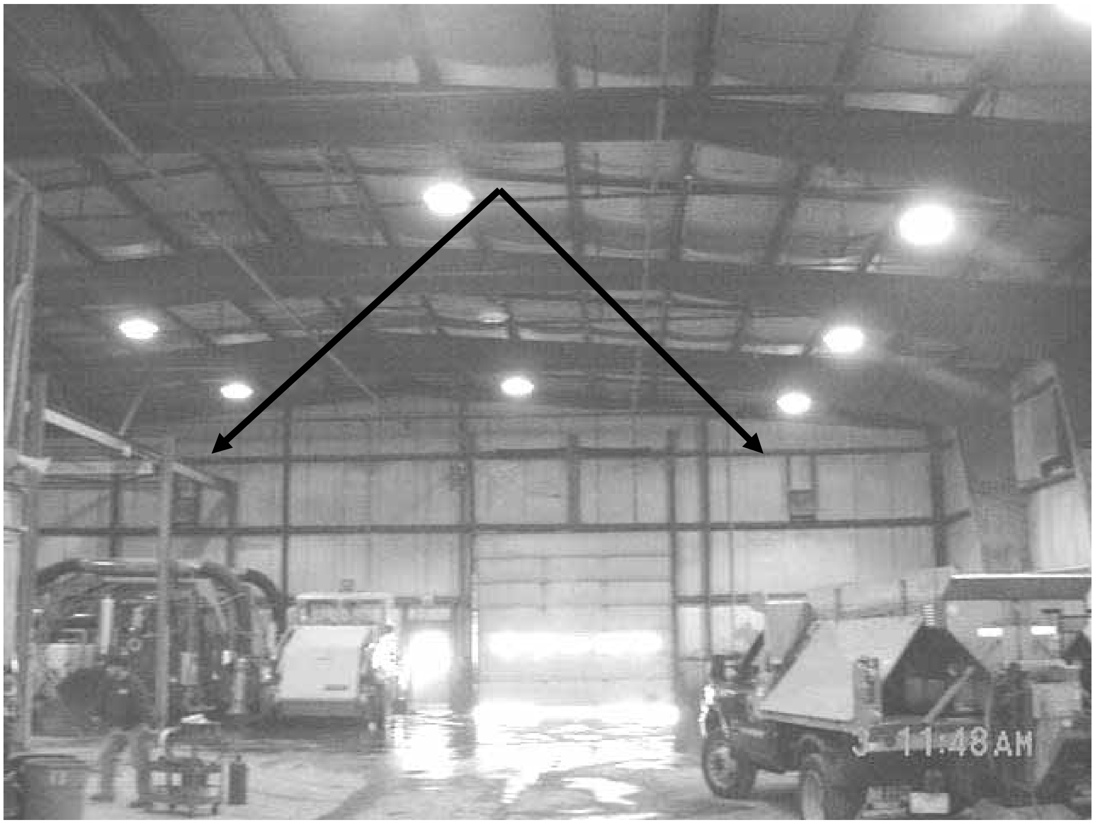
Picture 6

Missing Ceiling Tiles Due to Plumbing Leak

Picture 7

Spaces Between Backsplash and Sink Countertop

Picture 8



Interior View of Garage, Arrows Indicate Two Exhaust Vents

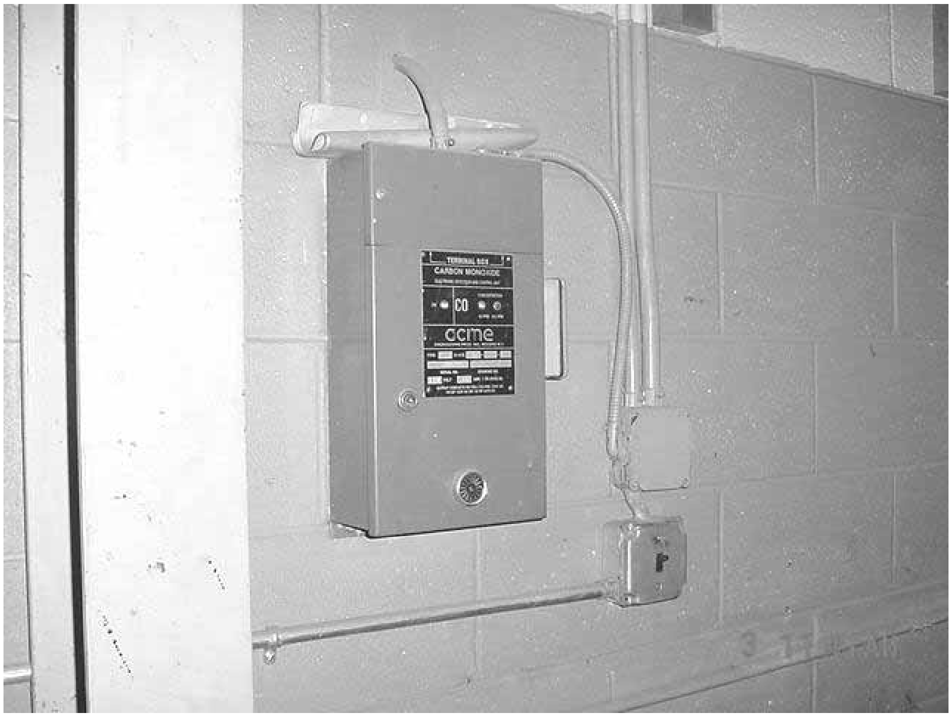
Picture 9

Exterior View of Garage, Arrows Indicate Two Exhaust Vents

Picture 10

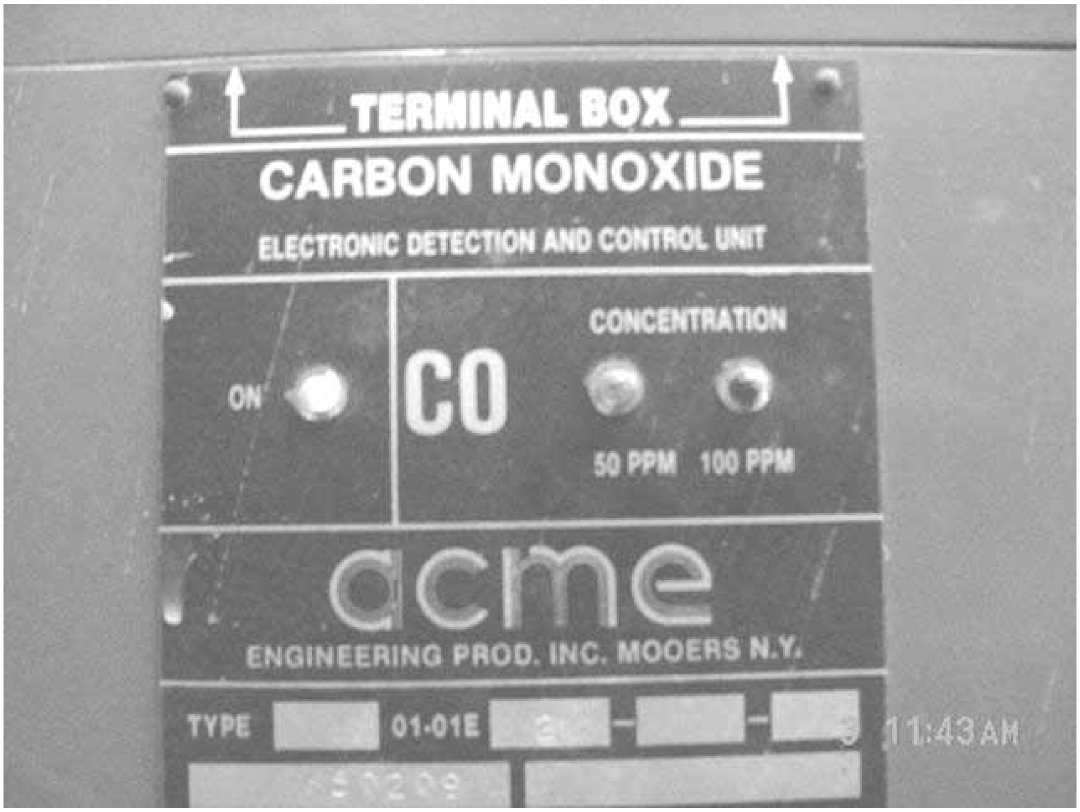
Exterior View of Four Make-Up Air Vents for Garage

Picture 11



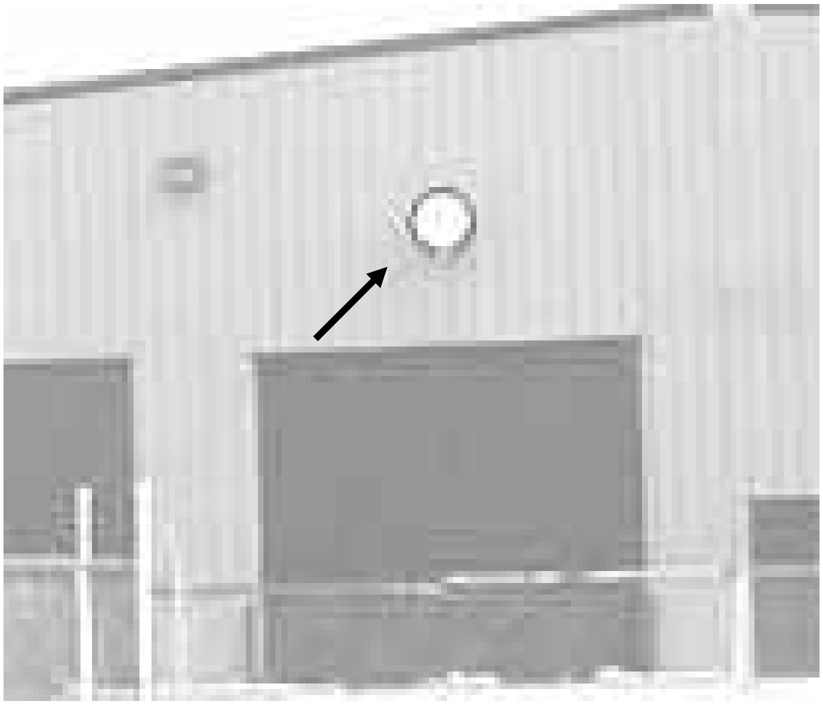
Wall-Mounted Carbon Monoxide Sensor Terminal Box in Garage

Picture 12



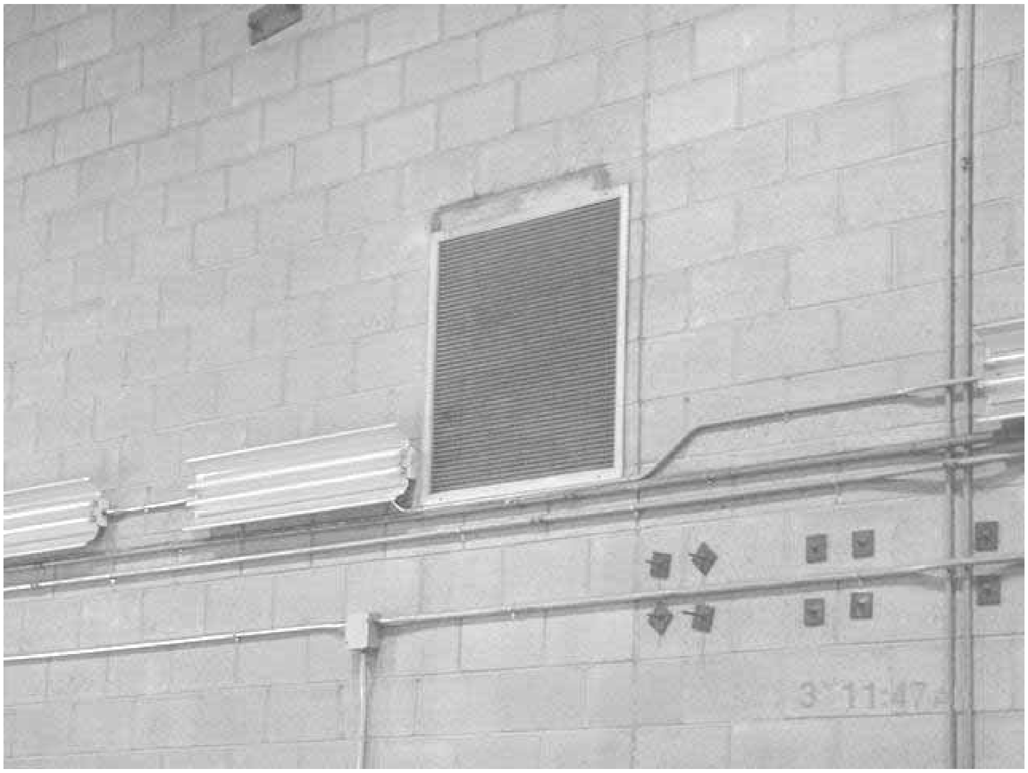
Close-up of Wall-Mounted Carbon Monoxide Sensor Terminal Box in Garage, Note Concentration Indicator Lights of 50/100 parts per million (ppm)

Picture 13



Exhaust Motor for Mechanics' Bay

Picture 14



Passive Vent in Common Wall between Mechanics' Bay and Garage

Picture 15

Spaces around Door to Mechanics' Bay that Does not close Properly

Picture 16

Parts Washer in Mechanics' Bay

Picture 17

Container with Motor Oil in Mechanics' Bay

TABLE 1

Indoor Air Test Results – Milford Highway Department, Milford, MA – March 3, 2005

Location	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	Ultrafine Particulates **1000p/cc^3	Temp (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background	324	ND	ND	14.8	32	14					Mostly sunny-cold, NW winds 10-15 mph, moderate traffic, 2 construction vehicles idling on the east and west sides of building
Shower/Bathroom	444	ND	ND		63	23	0	Y	Y	Y	Exhaust vent not operating
Conference Room	495	ND	ND	4.9	66	24	0	Y	Y	Y	
Leclaire Office	546	0-1	ND	6.1	67	22	0	Y	Y	Y	
Main Office	586	0-1	ND	6.3	69	21	3	N	Y	Y	Photocopier, missing ceiling tiles
Main Office Restroom								N	Y	Y	Exhaust vent not operating
Lunch Room	492	0-1	ND	15.8	69	21	2	Y	Y	Y	Spaces countertop/sink
Lunch Room Hallway	523	1	ND	20.0	69	21	0				Missing ceiling tiles
Locker Room	471	1-2	ND	32.6	68	22	0	Y	Y	Y	Missing ceiling tiles

*** ppm = parts per million parts of air**

****1000p/cc^3 = particles per cubic centimeter parts of air**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

Table 1-1

TABLE 1

Indoor Air Test Results – Milford Highway Department, Milford, MA – March 3, 2005

Location	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	Ultrafine Particulates **1000p/cc^3	Temp (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Mechanics' Bay	508	1	*13.2/ 1.0	34.9	68	18	4	N	Y passive	Y	*TVOC 13.2 during spray painting reduced to 1.0 in 5 minutes, welding, parts washer-solvents, ceiling fans, passive vents into large garage bay
Foreman's Office	457	1	ND	34.0	69	19	0	N	N	N	Doors open between garage and mech bay
Garage	402	ND	ND	34-46.0	59	26	3	N	Y	Y	Sweeping of floor, washing of vehicles, opening and closing of garage doors, CO-sensor on wall, local exhaust mannually activated by wall switch

ND = non detect

*** ppm = parts per million parts of air**
****1000p/cc^3 = particles per cubic centimeter parts of air**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

Table 1-2